UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

HANDLING AND SHIPPING TESTS WITH NEW POTATOES FROM KERN COUNTY, CALIFORNIA

W. R. BARGER, G. B. RAMSEY, R. L. PERRY,
and JOHN H. MacGILLIVRAY

Results of a coöperative investigation conducted by the United States Department of Agriculture Bureau of Plant Industry and the California Agricultural Experiment Station

BULLETIN 664
April, 1942

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

ACKNOWLEDGMENTS

Acknowledgment is made to the following persons and firms for furnishing carlot shipments and other smaller lots of potatoes for the tests: Chris Handel and Son, Shafter Coöperative Potato Growers, Atlantic Commission Company, Albert Miller and Company, D. W. Ferguson, United Produce Company, C. G. Rice, Battaglier-Burger, Fred Bryan, W. B. Camp, and Phil Ohanneson.

Appreciation is also expressed to the following persons, firms, and agencies for assistance of various kinds furnished during the investigation: W. T. Pentzer and J. S. Wiant, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture; United States Agricultural Marketing Service; Wm. Rutledge, State-Federal Inspection Service, Shafter, California; M. A. Lindsay, Kern County Farm Advisor; Union Ice Company; L. and S. Precooling Company; Food Machinery Corporation; Santa Fe Railroad; Pacific Fruit Express Company; and Southern Pacific Railroad and connecting lines.

HANDLING AND SHIPPING TESTS WITH NEW POTATOES FROM KERN COUNTY, CALIFORNIA[1,2]

W. R. BARGER,[3] G. B. RAMSEY,[4] R. L. PERRY,[5] AND JOHN H. MacGILLIVRAY[6]

INTRODUCTION

THE IRISH POTATO, grown as an early crop and harvested before mature, is a major crop in Kern County, California. During the three months from April through June, about 12,000 carloads of these new potatoes are shipped from this district, about one third of which go to eastern markets. Although shipments have arrived reasonably free from decay, severe discoloration of the surface of the tubers has occurred in transit and has resulted in low market prices for many shipments.

In tests made early in the 1938 shipping season by the United States Agricultural Marketing Service, small lots of White Rose potatoes, the variety commonly grown, were shipped by express to one of the authors of the present paper, at Chicago. As the results showed, surface browning of Kern County potatoes occurs at skinned areas and is accentuated whenever the tubers are exposed to hot, dry wind either before washing or in transit to market.

The present report summarizes the results of all test shipments of new potatoes from Kern County made since 1938. Particular attention was paid to various handling practices and different methods of refrigeration.

REVIEW OF LITERATURE

Many investigators have studied the process of normal healing or suberization of potato wounds. This healing process of skinned and "feath-

[1] Received for publication November 14, 1941.

[2] The investigations reported herein were conducted coöperatively by the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and the divisions of Truck Crops and Agricultural Engineering of the University of California.

[3] Associate Physiologist, Bureau of Plant Industry, United States Department of Agriculture.

[4] Senior Pathologist, Bureau of Plant Industry, United States Department of Agriculture.

[5] Associate Professor of Agricultural Engineering and Associate Agricultural Engineer in the Experiment Station.

[6] Assistant Professor of Truck Crops and Associate Olericulturist in the Experiment Station.

ered" tubers has been found by Artschwager[7] and by Werner[8] to require the same conditions of moderately high temperature (70° F) and high humidity necessary for the rapid healing of cut wounds. Abnormal darkening or surface browning of skinned tubers is attributed by Peacock[9,10] to solar and sky radiation. He found it to be less when the tubers were dug during early morning and late afternoon than when they were dug at midday. Rose and Fisher[11] report browning to result from rapid loss of moisture from the skinned surface and to be independent of sun scald and heat scald. It would appear that discoloration usually occurs whenever conditions are unfavorable for normal healing of wounds.

In other new-potato regions, notably Louisiana, Florida, and Kansas, precooling has been found effective for the control of bacterial soft rot.[12-15] Excessive moisture due to washing contributes to early development of decay. By precooling the load in the cars, both excess moisture and field heat can be removed at the same time. The precooling equipment used consisted of two types: one system used fans at the top bunker openings of the cars to draw air up through the ice in the bunker and force it down through the load whereas the other system used mechanical refrigeration and blew cold air through the doorway of the car to circulate the air through the load and over mechanically refrigerated coils. No ice was needed in the bunkers of cars cooled with the latter method. With both systems the circulating air absorbs moisture from the wet potatoes and deposits it as water on the ice or as frost on the coils. In Kern County, dry, hot weather prevails during harvest, and this condition may account for the very small amount of bacterial soft rot which occurs in these potatoes. Surface browning, however, is more prevalent in this section than in more humid localities.

[7] Artschwager, Ernst. Wound periderm formation in potato as affected by temperature and humidity. Jour. Agr. Research 35:995–1000. 1927.

[8] Werner, H. O. Wound healing in potatoes (Triumph variety) as influenced by type of injury, nature of initial exposure, and storage conditions. Nebraska Exp. Sta. Research Bul. 102:1–40. 1938.

[9] Peacock, W. M. Healing of potatoes skinned during harvest as affected by temperature, humidity, and solar and sky radiation. Amer. Soc. Hort. Sci. Proc. 28:266–69. 1931.

[10] Peacock, W. M., R. C. Wright, and T. M. Whiteman. Controlling the shrinkage of skinned potatoes in storage. Amer. Soc. Hort. Sci. Proc. 29:415–19. 1932.

[11] Rose, Dean H., and D. F. Fisher. Desiccation effects on skinned potatoes. American Potato Journal 17:287–89. 1940.

[12] Poole, Wiley D., and Harold T. Barr. Precooling and drying of washed Irish potatoes. Louisiana Agr. Exp. Sta. Bul. 332:1–22. 1941.

[13] Ruehle, George D. Bacterial soft rot of potatoes in southern Florida. Florida Agr. Exp. Sta. Tech. Bul. 348:1–36. 1940.

[14] Wright, R. C., W. V. Hukill, and E. A. Gorman. Preliminary investigations on the precooling and drying of washed early potatoes in Florida. U. S. Dept. Agr. Bur. Plant Ind. 1936. (Mimeo.)

[15] Decker, S. W. Problems in the marketing of Kaw Valley potatoes. Kansas State Horticultural Society Bien. Rept. 45:55–65. 1940.

METHODS OF HANDLING POTATOES IN KERN COUNTY

Kern County potatoes are dug by machine, picked up in sacks, and hauled to packing sheds to be washed. Culls and decayed potatoes are left on the ground. At the packing sheds the stock is washed, graded, placed in new sacks, and loaded into refrigerator cars.

Potato-washing machines use revolving Tampico fiber brushes and water sprays. Upon leaving the washer the tubers are conveyed on a

Fig. 1.—A "2 and 3 high—3 and 6 wide" load of 100-pound potato sacks. A portion of the second layer has been removed at the doorway to show the arrangement of the load.

long divided belt past the graders, who re-sort the stock so that finally each division of the belt contains but a single grade. The tubers drop from the end of the grading belt into sacks. Operators fill, weigh, and sew the sacks shut and then truck them into the cars. Although no provision is made to dry the potatoes after washing, considerable drying occurs during grading, and no moisture drains from the finished sacks. The common load is of the "through load—2 and 3 high—3 and 6 wide" type; it consists of 300 sacks of 100 pounds net weight. With such a load the sacks of the bottom layer are placed upright in six rows, from wall to wall; and those of the second layer are laid flat, end to end, three wide across the car on top of the bottom layer. These two layers are continued solid across the doorway, making a load that requires no wooden bracing to prevent shifting of the sacks in transit. The third layer is made like the second but extends only about four sacks in from the ends of the car (fig. 1).

TABLE 1

Shipping Treatments of Test Cars and Condition of Potatoes on Arrival

Classification concluded on opposite page

Test car	Date shipped	California shipping point	Destination	Routing*	Icing station	Method of refrigeration†
				Shipping tests in 1938		
A	May 31	Shafter	Chicago	Santa Fe	Shafter	Rule 240
B	June 1	Shafter	Chicago	Santa Fe	.....	Ventilation
C	June 2	Shafter	Chicago	Santa Fe	.....	Ventilation
D	June 9	Shafter	Chicago	Santa Fe, Wabash	Bakersfield	Rule 240
D	June 9	Shafter	Chicago	Santa Fe, Wabash	Bakersfield	Rule 240
E	June 9	Shafter	New York	Santa Fe, C.G.W., N.K.P., Erie	Needles	Rule 240
E	June 9	Shafter	New York	Santa Fe, C.G.W., N.K.P., Erie	Needles	Rule 240
E	June 9	Shafter	New York	Santa Fe, C.G.W., N.K.P., Erie	Needles	Rule 240
E	June 9	Shafter	New York	Santa Fe, C.G.W., N.K.P., Erie	Needles	Rule 240
F	June 10	Shafter	Chicago	Santa Fe, C.&A.	Bakersfield	Rule 240
F	June 10	Shafter	Chicago	Santa Fe, C.&A.	Bakersfield	Rule 240
F	June 10	Shafter	Chicago	Santa Fe, C.&A.	Bakersfield	Rule 240
F	June 10	Shafter	Chicago	Santa Fe, C.&A.	Bakersfield	Rule 240
				Shipping tests in 1939		
G	June 9	Edison	Chicago	S.P., U.P., C.&N.W.	.....	Ventilation
H	June 9	Edison	Chicago	S.P., U.P., C.&N.W.	Roseville	Rule 240
I	June 22	Shafter	Chicago	Santa Fe	Needles	Rule 240
I	June 22	Shafter	Chicago	Santa Fe	Needles	Rule 240
J	June 28	Shafter	Chicago	Santa Fe, W.P., D.&R.G.W., Santa Fe	.....	Ventilation
J	June 28	Shafter	Chicago	Santa Fe, W.P., D.&R.G.W., Santa Fe	.....	Ventilation
K	June 28	Shafter	Chicago	Santa Fe	Needles	Rule 240
K	June 28	Shafter	Chicago	Santa Fe	Needles	Rule 240
L	June 29	Shafter	Chicago	Santa Fe, W.P., D.&R.G.W., U.P., C.&N.W.	Bakersfield	Rule 240
M	June 29	Shafter	Chicago	Santa Fe, W.P., D.&R.G.W., U.P., C.&N.W.	Stockton	Rule 240
				Shipping tests in 1941		
N	April 22	Edison	Detroit	S.P., U.P., Wabash	Bakersfield	Rule 254A
O	April 22	Edison	Detroit	S.P., U.P., Wabash	Bakersfield	Rule 240‖
P	May 7	Shafter	Chicago	Santa Fe	Bakersfield	Rule 240
Q	May 7	Shafter	Chicago	Santa Fe	Needles	Rule 240
R	May 9	Edison	Chicago	S.P., U.P., C.&N.W.	Bakersfield	Rule 240
S	May 9	Edison	Chicago	S.P., U.P., C.&N.W.	North Platte	Rule 240
T	May 10	Lerdo	Chicago	S.P., U.P., C.&N.W.	Roseville	Rule 240
U	May 10	Lerdo	Chicago	Santa Fe	Needles	Rule 240
V	May 28	Shafter	Detroit	Santa Fe, C.B.&Q., Wabash	.....	Ventilation
W	May 28	Lerdo	Chicago	S.P., U.P., C.&N.W.	Roseville	Rule 240

* Abbreviations of railroads: C.G.W. = Chicago Great Western; N.K.P. = Nickel Plate; C.&A. = Chicago and Alton; S.P. = Southern Pacific; U.P. = Union Pacific; C.&N.W. = Chicago and Northwestern; D.&R.G.W. = Denver and Rio Grande, Western; W.P. = Western Pacific; C.B.&Q. = Chicago, Burlington and Quincy.

† Rule 240: initally iced after loading, not re-iced. Rule 254A: initially iced before loading (pre-iced), replenished after loading, not re-iced.

‖ This car was iced before loading but not replenished or re-iced after loading.

TABLE 1 (*Continued*)

SHIPPING TREATMENTS OF TEST CARS AND CONDITION OF POTATOES ON ARRIVAL

Test involved in shipping potatoes	Loading treatment or loading condition of potatoes‡	Per cent discolored	Per cent decay	Remarks on condition at arrival
Shipping tests in 1938				
Precooling with ice water shower	Precooled to 48° F.	0	0	Firm and white
Precooling with ice water shower	Precooled to 50° F.	10	1–3	Sticky surface
Precooling with ice water shower	Not precooled	15–20	10	Advanced type of decay
Condition, location in car	Top doorway	10–20	1	Many scalded
Condition, location in car bunker and top doorway	Bottom bunker	10–20	6	Many scalded
Maturity and skinning	Immature,§ slightly skinned	5	0	Discolored second day on market (22 per cent)
Maturity and skinning	Immature,§ severely skinned	18	0	Discolored second day on market (91 per cent)
Maturity and skinning	Mature,¶ slightly skinned	3	0	Discolored second day on market (18 per cent)
Maturity and skinning	Mature,¶ severely skinned	12	1	Discolored second day on market (80 per cent)
Drying after washing	Dried after washing (fan), top doorway	10–20	5	Sticky surface
Drying after washing	Water poured on sack in car, top doorway	5–10	9	Sticky surface
Drying after washing	Dried after washing (fan), bottom bunker	5–10	10	Sticky surface; bottom bunker tubers moist
Drying after washing	Water poured on sack in car, bottom bunker	2–3	10	Sticky surface
Shipping tests in 1939				
Ventilation or icing	No treatment	5–10	5	Some browning
Ventilation or icing	No treatment	2–3	0	Less browning than car G
Covered or not covered	Hauled exposed	2	3	Advanced decay, bag wet
Covered or not covered	Hauled under tarpaulin	0	0	Bright, clean
Condition, location in car	Mature, top doorway	10	2	Fair condition
Condition, location in car	Mature, bottom bunker	5	2	Less browning than in doorway
Condition, location in car	Immature, top doorway	8	14	Many scalded
Condition, location in car	Immature, bottom bunker	10	2	Browning less than at doorway
Immediate or delayed icing	Iced immediately	2	5	Sticky surface
Immediate or delayed icing	Iced in 30 hours	10	20	Some advanced decay
Shipping tests in 1941				
Blower precooling or not precooled	Precooled by bunker blowers	5–10	..	Slightly discolored
Blower precooling or not precooled	No treatment	0	..	Condition better than car N
Condition, immediate or delayed icing	Late blight areas marked**	5–10	0	Slight increase in lesion area, no spread to others
Condition, immediate or delayed icing	Late blight areas marked**	2–3	0	Slight increase in lesion area, no spread to others
Condition, immediate or delayed icing	Late blight areas marked**	5–10	1	Blight increase (1 per cent)
Condition, immediate or delayed icing	Late blight areas marked**	5–10	1	Bacterial rot (1 per cent); slight increase in lesion area
Condition, northern or southern route	Late blight areas marked**	5–10	1	Bacterial rot, slight increase in lesion area
Condition, northern or southern route	Late blight areas marked**	5–10	5	Late blight and bacterial rot
Condition, ventilation or icing	Late blight areas marked**	15	0	No spread of blight to sound tubers
Condition, ventilation or icing	Late blight areas marked**	2–3	1	Decay; sticky surface; slight increase in lesion area

‡ Test sacks were placed in top doorway unless otherwise listed.
§ Immature, dug 100 days after planting.
¶ Mature, dug 115 days after planting.
** Late blight lesions outlined with India ink before shipping.

Rail shipments to eastern markets are routed via Needles (California) through Williams (Arizona), Belen (New Mexico), Kansas City (Missouri), to Chicago (Illinois); or through Stockton (California), Winnemucca (Nevada), Salt Lake City or Ogden (Utah), and eastward through either Colorado or southern Wyoming.

Early in the season the cars are forwarded under ventilation, refrigeration being used later during hot weather. Refrigerator cars are loaded "dry" (without ice) and are initially iced at Bakersfield or Calwa on the morning after loading; or the shipper may elect to delay the icing until Needles or Roseville or any other regular icing station. Generally the icing instruction to the railroad follows shippers' tariff Rule 240: "Initial ice only—do not re-ice." Temperatures obtained in transit will be discussed later. With car N, Rule 254A was followed: "Initially iced before loading (pre-iced), replenished after loading, not re-iced."

OUTLINE OF THE TESTS

The general plan of the investigations was to determine how various handling and shipping practices affect the carrying quality of new potatoes. Test bags for inspection were placed in top doorway, unless otherwise noted in table 1. The routings of the cars containing test shipments, method of refrigeration, and nature of experiments involved are shown in table 1.

Records of temperatures in transit were obtained by placing recording thermometers in sacks of potatoes that were loaded close to the ice bunker or in the doorway of the car. The various transit conditions studied included: (1) ventilation, (2) precooling with portable blowers in pre-iced cars, (3) precooling with ice water before loading in dry cars, and (4) immediate and deferred initial icing of the cars after they had been loaded (table 1). Minimum and maximum outside temperatures encountered by the cars en route were obtained from United States Weather Bureau records.

In some cars, a few sacks were weighed to determine shrinkage in transit. For test purposes, some lots were dried after washing; some were exposed to sunlight and wind before washing; and others were dug at different maturities and shipped to determine the best handling practices. Upon arrival at destination, the tubers were inspected for condition.

In other tests, skinned tubers were exposed to a drying wind and were then held for 7 days under controlled temperature and humidity at Fresno. Exposure to dry wind simulated conditions occurring in the field during digging and hauling. The holding period of 7 days was similar to the time in transit to Chicago. In these tests, the potatoes were

held at 50° F with 85 per cent relative humidity, and at 70° with 60 per cent relative humidity, to represent conditions encountered in refrigerated and ventilated shipments respectively. Some lots were shifted from one temperature and humidity to another, to approximate transit conditions of immediate and delayed icing and also that of having the ice melt out during the first 4 or 5 days en route.

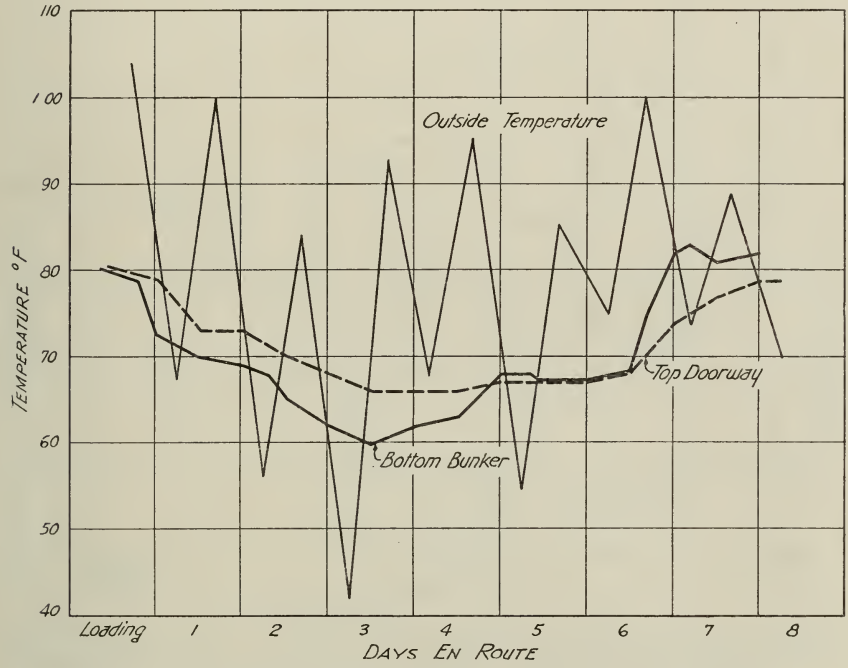

Fig. 2.—Temperatures of potatoes in car J, standard ventilation, from Shafter to Chicago, June 28 to July 6, 1939.

In the majority of the tests White Rose potatoes were used; but Bliss Triumph, a minor variety in this area, was used in a holding test at Fresno.

RESULTS AND DISCUSSION OF SHIPPING TESTS

Temperatures in Transit under Ventilation.—Temperatures obtained in a load of potatoes under ventilation from Shafter to Chicago via Stockton, June 28 to July 6, 1939, are shown in figure 2. Sacks near the bottom bunker opening cooled faster and to a lower point than those at the doorway. Judging from weather reports during the time of this shipment, the car encountered night temperatures of 75° to 80° F, and day temperatures of 90° to 100° between Kansas City and Chicago. The high outside temperature during this part of the trip is noticeable inside the

car by the rapid rise in the temperature of the load. With this test the potatoes in the doorway cooled from a temperature of 80° to about 65° during the first 3 days and would have remained at about this temperature had it not been for the hot weather encountered near Chicago. With two cars shipped under ventilation via Needles, temperatures

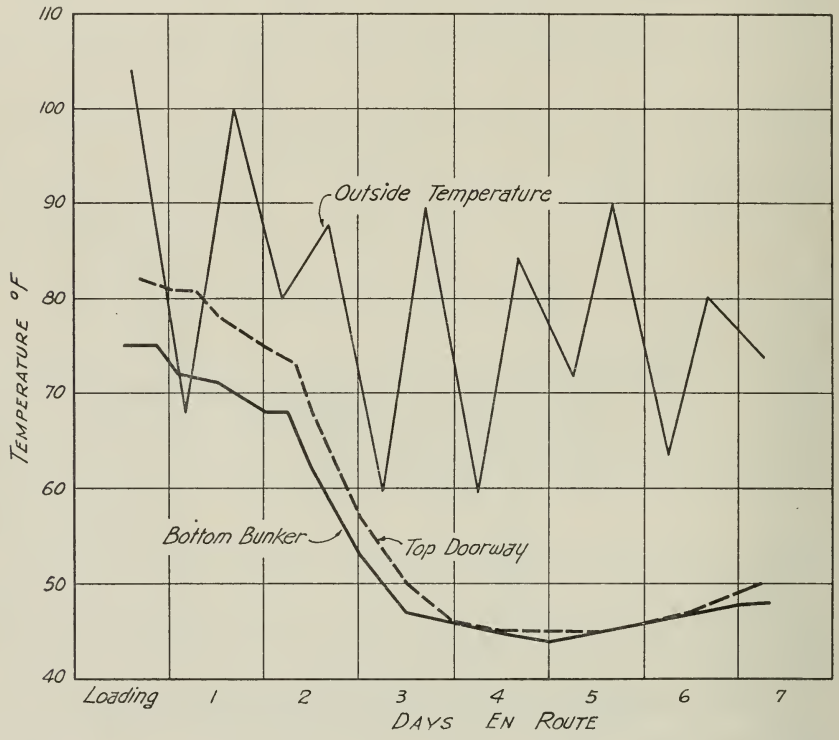

Fig. 3.—Temperatures of potatoes in car K from Shafter, to Chicago, June 28 to July 5, 1939. Iced at Needles in evening of first day en route.

similar to those obtained via Stockton were found during the first part of the trip (fig. 5, car V; fig. 8, car C) and cool weather east of the mountains during these tests kept the loads from warming up.

Temperatures in Transit under Refrigeration.—Temperatures in transit under initial icing at Needles (about midnight of the first day en route) are shown in figure 3. The end of the car (bottom bunker) was loaded with potatoes dug and washed early in the morning, whereas the doorway position was filled with tubers dug and washed in the afternoon. The weather was clear, minimum 67° and maximum 105° F. The potatoes dug in the afternoon were considerably warmer when loaded than those dug in the morning, and consequently it took longer for them to

cool to a definite point. After the car was iced the entire load cooled to about 45° in 36 hours and remained between 45° and 50° for the remainder of the trip. Figures 4 and 5 compare the temperatures under refrigeration and ventilation of tests made in 1939 and 1941.

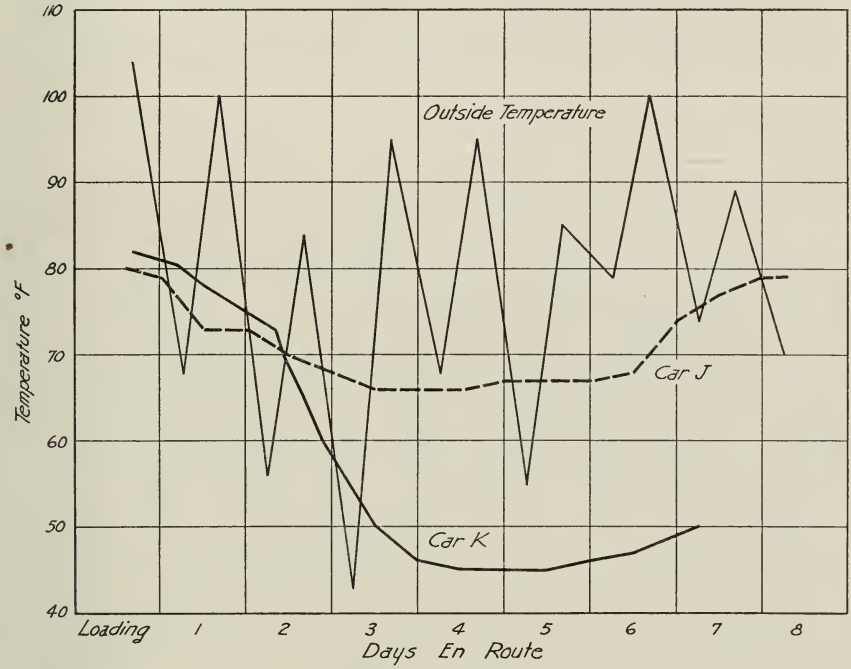

Fig. 4.—Top doorway temperatures of potatoes from Shafter to Chicago, June 28 to July 5, 1939. Car J was shipped by standard ventilation and car K was iced at Needles in the evening of the first day en route.

Temperatures of cars iced at the first icing station are compared with temperatures of cars receiving delayed icing shown in figures 6 and 7. Both northern and southern routes were used.

Over the northern route (fig. 6) car M was initially iced at Stockton about 30 hours after loading, whereas car L was iced at Bakersfield about 12 hours after loading.

Over the southern route (fig. 7) car P was initially iced at Bakersfield about 12 hours after loading and car Q was initially iced at Needles about 30 hours after loading.

The vents are opened for all cars en route to an initial icing station and when icing is delayed beyond the first station the load cools under ventilation if the temperature outside is sufficiently low; but a continuous cooling of the load to a temperature between 45° and 50° F does not occur until after the car is iced.

The cars over the northern route were shipped during hot weather (late June) and upon arrival at Chicago the supply of ice in the bunkers was nearly depleted as indicated by the rise in temperature of the load after the fifth and sixth days en route. The cars over the southern route encountered moderate weather (early May) and arrived at Chicago with ice in the bunkers amounting to about 600 pounds in each end of the car iced at Needles and half this amount in the car iced at Bakersfield.

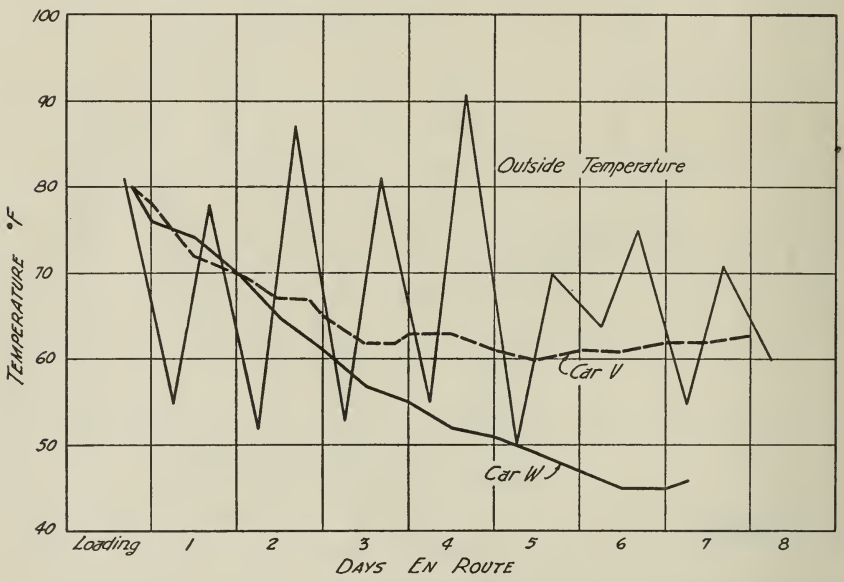

Fig. 5.—Top doorway temperatures of potatoes from Shafter shipped by standard ventilation to Detroit (car V); and (car W) shipped to Chicago with initial icing at Roseville, the evening of the first day en route. Days in transit, May 28 to June 4, 1941.

Temperatures in Transit after Hydrocooling.—Two cars of hydrocooled (water-cooled) potatoes were shipped in 1938 and temperatures were compared with a ventilated shipment. Before being loaded, the potatoes of two cars (A and B, fig. 8) were hydrocooled to about 50° F by placing the sacks one layer deep on a conveyer and passing them through a shower of ice water. The temperature of the water was maintained at about 35° by recirculation through a tank containing crushed ice; each sack remained in the hydrocooler about fifteen minutes, during which the temperature of the potatoes was lowered about 30 degrees. About 4½ tons of ice was used for cooling the potatoes of car A, from an initial temperature of 80° average to a final temperature of 48° average. Car A was initially iced at the packing shed and maintained a load temperature of 48° to 51° at the doorway for the entire trip to Chicago with-

out re-icing, and reached its destination with the bunkers one third full of ice.

Car B was forwarded under ventilation. The load temperature at the doorway rose from 50° to 62° F during the first 10 hours en route and remained between 62° and 65° until the third day, when the clock of the

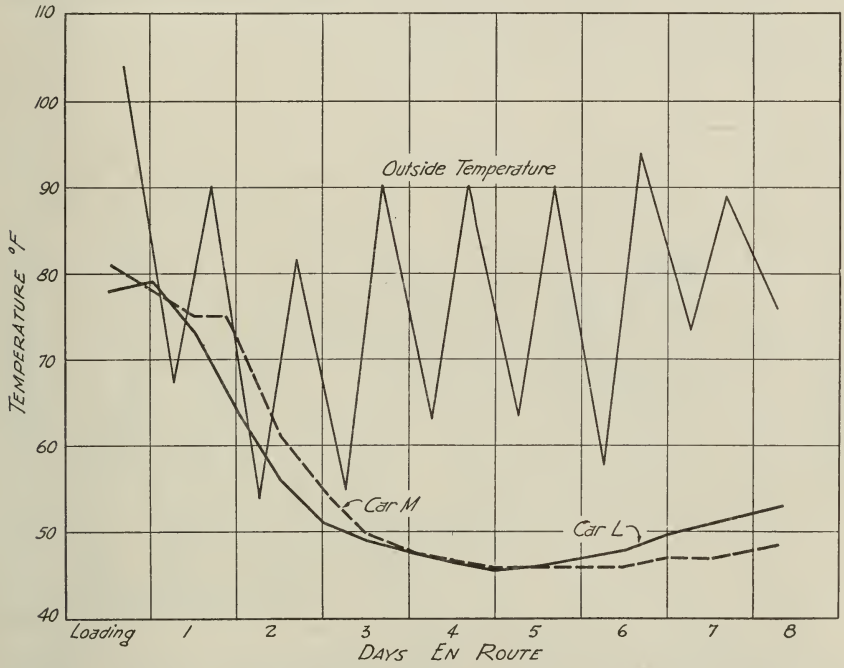

Fig. 6.—Bottom doorway temperatures of potatoes shipped from Shafter to Chicago, June 29 to July 7, 1939. Car L was iced at Bakersfield the early morning of the first day and car M was iced at Stockton the evening of the first day en route.

recording thermometer stopped. A record of 60° upon arrival at Chicago indicates a temperature of 60° to 65° for the entire trip.

Car C (fig. 8) was shipped under ventilation for comparison. The load cooled to 67° F during the first 3 days and remained between 67° and 70° for the remainder of the trip.

Temperatures in Transit after Precooling in the Car.—In one test, temperatures of a precooled load were compared with those of a load placed in a pre-iced car. Both cars were iced before delivery to the packing shed. The load of car O (fig. 9) was not precooled and the car received no ice other than the initial supply. The load of car N was precooled for 6 hours with portable blowers and the bunkers were replenished with ice at Bakersfield after precooling was finished. The portable blowers, one for each end of the car, were suspended above the ice in the bunkers

and drew the air from the floor of the car up through the ice and discharged it over the top of the load. Canvas was used to close the top bunker opening at all places except the discharge of the blower. The ice was salted in order to maintain an air blast of 40° to 45° F at the blower.

Temperature of potatoes at the doorway of both cars is shown in figure 9. Loading was finished at 4 p.m. and at midnight after the precooled

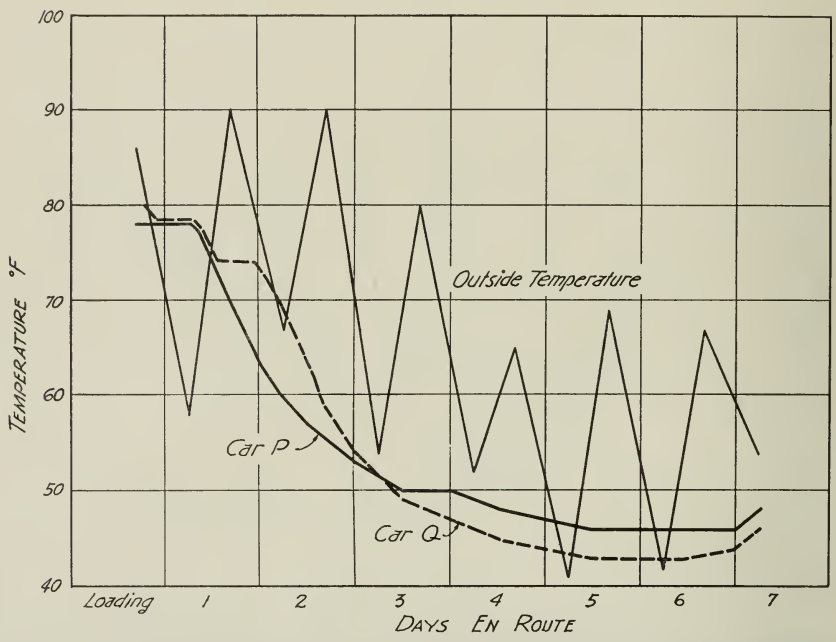

Fig. 7.—Doorway temperatures of potatoes from Shafter to Chicago, May 7 to 14, 1941. Car P was iced at Bakersfield in the early morning and car Q at Needles in the late evening of the first day en route.

car N had been blown for 6 hours the potatoes had cooled from a temperature of 80° F at the start to 53.5°, whereas the potatoes in car O (not precooled) were 66°, having cooled from a temperature of 82°.

After the precooled car was replenished with ice, it continued to cool to a temperature of 40° F. This point was reached on the third day and the temperature remained between 39° and 42° for the remainder of the trip. The temperature of the nonprecooled car dropped at a fairly uniform rate to 52°, which was recorded about 20 hours after loading. From then on the load cooled slowly for 3 days, reaching 44° F, the minimum temperature for the trip. During the next 4 days, the load of the nonprecooled car warmed up gradually to a final temperature of 50° F upon arrival at Detroit.

Condition upon Arrival at Market.—When the test shipments in the twenty-three cars of White Rose potatoes described herein reached their destinations (usually Chicago), their condition on arrival at the market was observed as noted in table 1. No significant difference in effect of northern and southern routes was disclosed by the only tests which compared routing directly (cars T and U).

Decay and Scald.—With the tests of 1938 and 1939, decay of any consequence occurred only in car C (table 1), which was a ventilated shipment without ice. Scald of field origin was found in only two cars (D and I, table 1). In this investigation all definitely sunken areas whether bleached or not were called scald. There was no attempt made to differentiate between sun scald and heat scald although the absence of bleaching indicates that the injury is caused by excessive heat rather than sunlight. When tubers were exposed to sunlight and heat in the field for 30 minutes or longer they showed bleached, sunken, scalded areas typical of sun scald.

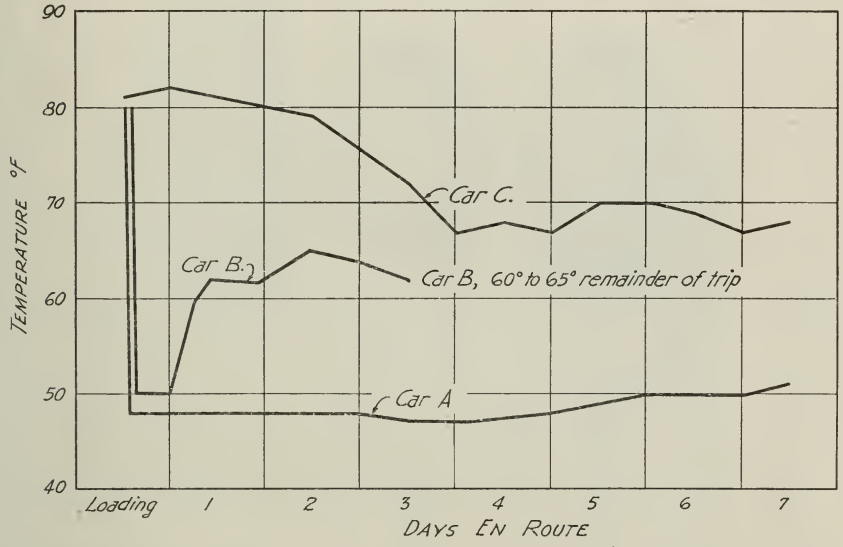

Fig. 8.—Doorway temperatures of potatoes from Shafter to Chicago, May 31 to June 9, 1938. The potatoes in car A were hydrocooled and iced at Shafter the evening of the day of loading; those in car B were hydrocooled and shipped under ventilation without ice; and those of car C were shipped under ventilation without hydrocooling.

In the tests of 1941 a few tubers showing late-blight infection were included with apparently sound potatoes in the experimental sacks. The late-blight lesions were outlined with India ink so that any spread of the disease in transit could be observed. Eight test shipments were made (cars P to W, table 1), including one forwarded under ventilation (car

V), one ventilated to North Platte before it was initially iced (car S), and the others initially iced on the first or second day after loading.

With these tests there was an increase during transit in the size of the blighted areas, but there was no spread of the disease to sound stock. In cars R and U, the amount of late blight appears to have increased in transit but this condition was due to the growth of small lesions that were not marked when the tubers were shipped.

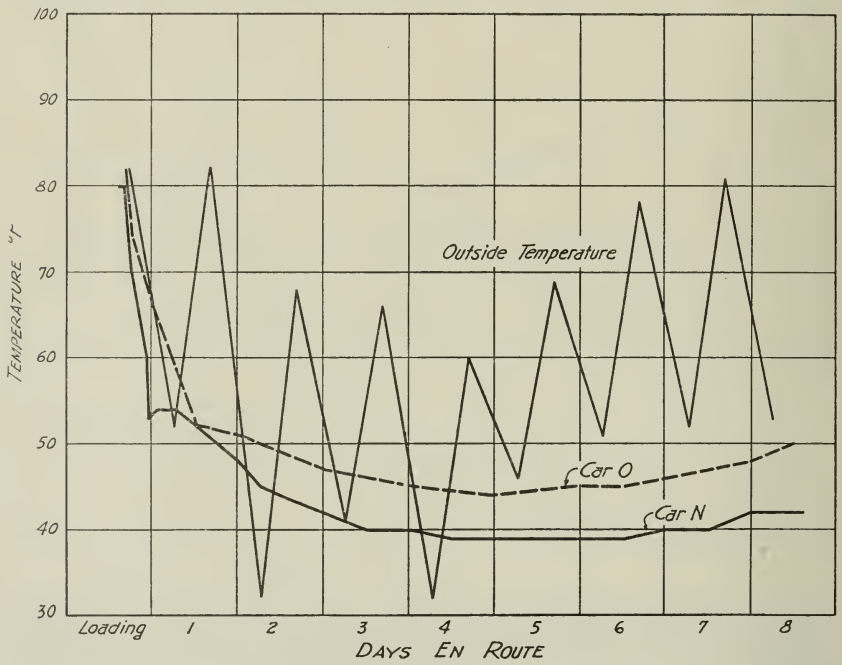

Fig. 9.—Top doorway temperatures of potatoes from Edison to Detroit, April 22 to 30, 1941. Car N was pre-iced, and precooled with inside fans and replenished according to Rule 254A. Car O was pre-iced, but not precooled nor replenished (Rule 240).

Although the temperature in transit during these tests was somewhat higher than 40° F, which is recommended for control of late blight in storage,[16] the results show that there is little danger that the disease will spread to sound potatoes during shipment under refrigeration. With holding tests, late blight has developed slower at 45° to 50° than at 60° to 65° despite higher humidity that prevailed at the lower temperatures.

Surface Browning and Stickiness.—Most of the deterioration resulted from browning of the skinned surface of the tuber and from a sticky condition of the skinned and scalded areas. Stickiness was an early stage

[16] Link, George K. K., and Glen B. Ramsey. Market diseases of fruits and vegetables—potatoes. U. S. Dept. Agr. Misc. Publ. 98:1–62. 1932.

of bacterial soft rot. Typical surface browning is illustrated in figure 10, *A*, and an extreme case in figure 10, *B*.

The refrigerated loads arrived in better condition than those which were ventilated. Icing at the first station (Bakersfield) gave somewhat better results than delayed icing. The hydrocooled load iced at Shafter (car A) arrived in perfect condition at a time when other cars (C and D) arrived with browning and decay. Car N, which was precooled with

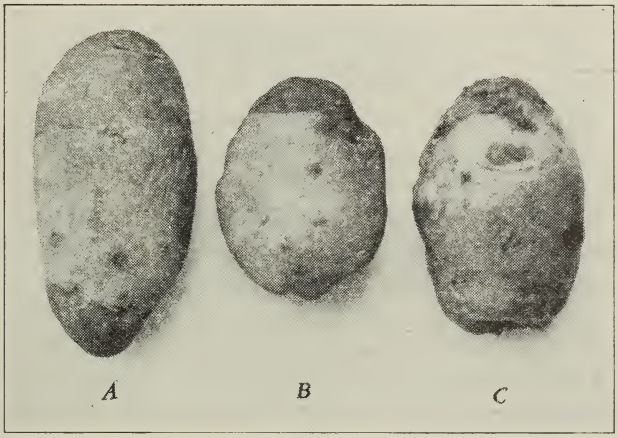

Fig. 10.—Surface browning of new White Rose potatoes: *A*, after 10 days at 70° F, and low humidity; *B*, after 10 days in electric refrigerator, with low humidity, which proves that low temperature when accompanied by low humidity does not prevent browning; and, *C*, which shows that a covering of vaseline on potatoes stored for 10 days at low humidity reduces moisture loss and browning.

portable car blowers, showed increased browning caused by the desiccating effect of the air blast.

There is usually more surface browning at the doorway than near the bunkers, partly because of slower cooling and greater possibility of drying. Excessive surface browning at the doorway also may be due to digging and loading this portion in the heat of the day and to the practice of leaving the doors open after the cars are loaded, which exposes the sacks to the hot, dry air prevailing in the Kern County area.

Effect of Drying after Washing.—Transit diseases, especially bacterial soft rot, have been controlled in the "early potato" districts of the humid eastern and southeastern parts of the United States by thoroughly drying the tubers after washing. In a shipping test with car F (table 1), some tubers were dried under a fan after washing, some were shipped without being dried, and others were made excessively wet by water poured over the sacks after they were loaded in the car. In the

doorway, where the air is of low humidity, the dry sacks had less sticky decay than the wet sacks. This difference was not apparent in the more humid part of the car near the bunker. The potatoes that were dried after washing became more discolored in transit than those that were not dried.

Effect of Maturity on Browning.—During 1938, it was possible because of a delay of about 2 weeks in the final planting of a field, to ship two lots of different age from the same field in car E; one lot was dug 100 days and the other 115 days after planting. Despite careful handwork the potatoes could not be removed from the hills without some skinning. The more mature tubers (115 days from planting) withstood the digging operation with somewhat less skinning. With each maturity, two experimental lots were prepared, one consisting of stock slightly skinned during digging, and the other of stock severely skinned. Discoloration was found greatest with immaturity and with severe skinning.

Effect of Sunlight and Wind.—Various lots of potatoes were exposed to wind, sunlight, and shade immediately after digging. Exposure to wind was accomplished by hauling at 20 to 30 miles per hour on a platform truck provided with a temporary canopy for shade. During 1938, a test[17] of this type was made on a hot, dry day (111° F) when the tuber temperature was 98° to 102°. During 1939, the test was repeated under air conditions of 82°, 25 per cent relative humidity, and tuber temperatures of 73° to 82° and the potatoes were held at Fresno.

Exposure to wind for 15 minutes on a hot day produced 79 per cent severe browning when the potatoes were shipped by express to Chicago in 1938. Exposure for the same time on a cool day produced 32 per cent when held at Fresno in a simulated test in 1939. Check lots of similar stock held stationary in the shade developed 11 per cent on a hot day and 9 per cent on a cool day. Browning was further increased by exposure to wind for longer periods.

On the hot day (111° F), tubers left on the ground in the sunlight for 30 minutes or more, developed scald. It developed in transit and was not apparent at time of shipping. On the cool day (82°) tubers spread on sod in sunlight for 1 hour failed to develop scald. The scald in the first test may have been caused by contact with hot soil.

RESULTS AND DISCUSSION OF HOLDING TESTS

Effect of Wind on Browning.—In the holding tests new potatoes were skinned at the bud end by rubbing with a towel and were stored

[17] The potatoes of this test were prepared at Shafter, California, and forwarded by express to Dr. Ramsey at Chicago by Mr. William Rutledge of the United States Agricultural Marketing Service.

for a week at 70° to 75° and at 50° to 55° F, in high and in low humidity at Fresno. The low humidity ranged from 35 to 60 per cent relative humidity; the high humidity from 80 to 90 per cent relative humidity.

Some lots were stored immediately after skinning, some were exposed to wind for a short time before storing, whereas others were protected from the wind with sacks or canvas. In the preparation of these samples,

TABLE 2

Loss in Weight of Skinned New White Rose Potatoes During a Seven-Day Storage Period

Lot	Storage temperature and humidity	Per cent loss in weight of the sample		
		Total in 2 days	Total in 4 days	Total in 7 days
A	70° F and 60 per cent relative humidity, through entire period	0.95	1.20	1.84
B	70° F and 60 per cent relative humidity, for 2 days followed by 5 days at 50° F and 85 per cent relative humidity	0.83	1.17	1.22
C	50° F and 85 per cent relative humidity, through entire period	0.64	0.76	0.84
D	50° F and 85 per cent relative humidity, for 4 days followed by 3 days at 70° F and 60 per cent relative humidity	0.40	0.52	0.60

wind velocities of 300 to 400 feet per minute were obtained with an electric fan. Air conditions then prevailing were 70° to 90° F and 25 to 50 per cent relative humidity. After being stored for a week to simulate the transit period to Chicago, the potatoes were inspected for surface browning, decay, and loss of weight.

Loss of Weight.—Table 2 shows the percentage of original tuber weight lost in still air of low (60 per cent) and high (85 per cent) humidity at 50° and 70° F. At 50° in high humidity, 0.84 per cent shrinkage in weight occurred in 7 days. This loss resembles that noted in a shipment of U. S. No. 1 stock to New York under refrigeration, in which a loss in weight of about 1 per cent was observed. When the cooling was delayed in tests simulating shipments with delayed icing, shrinkage was increased. Graphs (fig. 11) derived from table 2 show greatest loss of weight during the first 2 days, when the wounds produced by skinning were fresh and the tubers were relatively warm. Considerably less shrinkage occurred with refrigeration than without it. When skinned potatoes were held at 70° F, with 60 per cent relative humidity, for 2 days and then placed under refrigeration (fig. 11, *B*), the retarding effect of low temperature on shrinkage was not noticeable until after the

fourth day. With others placed under refrigeration immediately after skinning (fig. 11, *D*) however, the rate of shrinkage did not increase upon removal to a warm, dry room after 4 days of refrigeration.

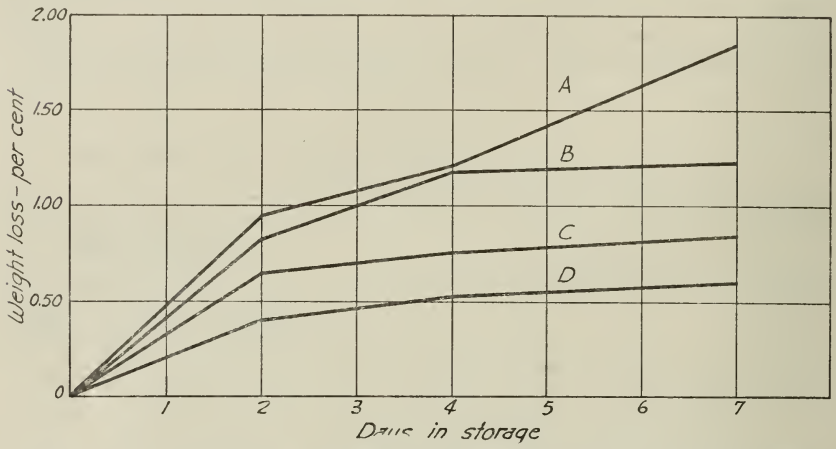

Fig. 11.—Loss of weight of skinned White Rose potatoes stored at Fresno. Lot A was held at 70° F and 60 per cent relative humidity for 7 days; lot B was held at 70° and 60 per cent relative humidity for 2 days, followed by 50° and 85 per cent relative humidity for 5 days; lot C was held at 50° and 85 per cent relative humidity for 7 days; and lot D was held at 50° and 85 per cent relative humidity for 4 days, followed by 70° and 60 per cent relative humidity for 3 days.

TABLE 3

LOSS OF WEIGHT OF NEW WHITE ROSE POTATOES DURING EXPOSURE TO WIND*

Per cent of skin removed†	Per cent loss in weight of sample	
	Total in 30 minutes	Total in 60 minutes
100	1.43	2.64
50	0.60	1.21
20	0.30	0.67
0	0.06	0.13

* Wind, 70° F; relative humidity, 50 per cent; velocity, 300 feet per minute.
† In partial skinning, the skin was removed from the bud end of the tuber only.

Table 3 shows loss in weight during exposure to drying wind. When potatoes were exposed to dry wind of about 4 miles per hour (300 to 400 feet per minute), the loss of weight during 1 hour ranged from 0.13 per cent with stock which was not skinned to 2.64 per cent for stock having all the skin rubbed off. Tubers with about 20 per cent of the skin removed lost 0.67 per cent during 1 hour.

Browning and Decay after Exposure to Wind.—The occurrence of browning and decay within the lots not exposed to the wind is shown in

table 4. When stored at 50° to 55° F with relative humidity of 85 to 90 per cent (group 3), less discoloration occurred than with 70° to 75° and relative humidity of 35 to 60 per cent (group 2). The temperature com-

TABLE 4

Condition of Skinned Tubers Held Under Different Temperatures and Humidities

Group no.	Temperature ° F	Relative humidity, per cent	Number of days held	Temperature ° F, in second period	Relative humidity, per cent, in second period	Number of days in second period	Condition of tubers			
							On the seventh day			After five additional days at 75° F and 45 per cent relative humidity
							Browning*	Surface	Cuts†	Browning‡
1	70	80	7	..	..	..	Slight	Dry	....	.....
	70	80	7	..	..	..	Slight	Dry	....	.....
	70	85	7	..	..	..	Medium	Dry	Moldy	Severe
2	75	35	7	..	..	..	Severe	Dry	Dry	.....
	75	35	7	..	..	..	Severe	Dry	Dry	.....
	75	35	7	..	..	..	Medium	Dry	Dry	.....
	70	60	7	..	..	..	Severe	Dry	Dry	Very severe
3	55	90	7	..	..	..	None	Dry	Dry	.....
	55	90	7	..	..	..	None	Dry	Dry	.....
	50	85	7	..	..	..	None	Dry	Dry	Medium
4	55	50	7	..	..	..	Severe	Dry	Dry	.....
	55	50	7	..	..	..	Severe	Dry	Dry	.....
	50	60	7	..	..	..	Severe	Dry	Dry	Very severe
5	70	80	2	55	90	5	None	Dry	Dry	.....
	70	85	2	50	85	5	Slight	Dry	Moldy	Medium
	75	35	2	55	90	5	Severe	Dry	Dry	.....
	70	60	2	50	85	5	Severe	Dry	Moldy	Severe
6	55	90	4	70	80	3	Slight	Dry	Dry	.....
	50	85	4	70	85	3	Medium	Dry	Dry	Medium
	55	90	4	75	35	3	Severe	Dry	Dry	.....
	50	85	4	70	60	3	Medium	Dry	Dry	Severe

* Degree of discoloration.
† "Moldy" indicates superficial mold on wounds of field and digging origin.
‡ No rot developed.

parable with cars shipped from Kern County is likely to be 70°, under ventilation and 50° under refrigeration. Low humidity probably prevails over the top of ventilated loads, but it probably does not extend below the top layer. High humidity at either temperature produced less browning than did low humidity, but increased slightly the superficial bacterial and mold growth on the tubers. The results also indicate that when

TABLE 5

CONDITION OF SKINNED TUBERS EXPOSED TO DRY WIND

Group no.	Time exposed to the wind or treatment before storage*	Storage temperature ° F	Relative humidity per cent in storage	Condition of tubers			
				On the seventh day			After five additional days at 75° F and 45 per cent relative humidity
				Browning†	Surface‡	Cuts§	Browning¶
7	15 minutes	70	85	Slight	Dry	Moldy	Medium
	15 minutes	70	60	Medium	Dry	Dry	Medium
	15 minutes	75	35	Very severe	Dry	Dry	.....
	15 minutes	55	90	Slight	Dry	Dry	.....
	15 minutes	50	85	Medium	Dry	Dry	Severe
8	30 minutes	70	85	Medium	Dry	Moldy	Medium
	30 minutes	70	60	Medium	Dry	Dry	Medium
	30 minutes	75	35	Very severe	Dry	Dry	.....
	30 minutes	55	90	Slight	Dry	Dry	.....
	30 minutes	50	85	Medium	Dry	Dry	Severe
9	2 hours	75	35	Severe	Dry	Dry	.....
	4 hours	70	80	Very severe	Dry	Dry	.....
	4 hours	75	35	Very severe	Dry	Dry	.....
10	30 minutes, then washed	70	60	Medium	Sticky	Moldy	Medium
	30 minutes, then washed	50	85	Medium	Dry	Dry	Severe
	30 minutes under tarpaulin, then washed	70	60	Slight	Dry	Dry	Slight
	30 minutes under tarpaulin, then washed	50	85	None	Dry	Dry	Medium
	30 minutes in wet sacks, then washed	70	60	Medium	Sticky	Moldy	Medium
	30 minutes in wet sacks, then washed	50	85	Slight	Dry	Dry	Medium
	Washed before and after 30 minutes' wind	70	60	Slight	Sticky	Moldy	Medium
	Washed before and after 30 minutes' wind	50	85	Slight	Dry	Dry	Medium

* Wind 70° F, 35 per cent relative humidity at 300 to 400 feet per minute, except for tests of group 10 where temperature was 90° F and 25 per cent relative humidity.
† Degree of discoloration.
‡ Sticky growth on new skin, probably an early stage of bacterial soft rot.
§ "Moldy" indicates superficial mold on surface of wounds of field and digging origin.
¶ No rot developed.

the tubers cool slowly (group 5), as occurs with delayed icing, more browning and decay result than when the tubers cool rapidly (group 3). Potatoes cooled rapidly and allowed to warm up under high humidity suffer less deterioration than potatoes cooled slowly under low humidity.

Table 5 shows the change developing in the condition of skinned tubers after exposure to dry wind. An exposure of 15 minutes caused surface browning during subsequent holding at low humidity regardless of the

temperature used, but not so at high humidity (group 7). Exposure for 30 minutes (group 8) caused medium to severe discoloration at both high and low humidities except in the lots held under refrigeration at high humidity, in which case discoloration was held down to slight or medium.

Group 10 (table 5) shows results of several treatments that might be applied in the field, including protecting the loads with wet or with dry tarpaulins during hauling from the field. All these lots were washed after they were exposed to the wind and were held at 70° F, with low humidity, and at 50°, with high humidity, to simulate conditions over the tops of ventilated and refrigerated loads. The tubers held at 70° developed sticky, skinned areas and moldy cuts, whereas those under refrigeration did not. The least discoloration followed the covering of tubers with a tarpaulin to protect them from the drying wind. Potatoes in the top sacks of the truck loads were washed separately and forwarded under refrigeration to Chicago. Those from the covered load (car I, table 1) arrived with no bacterial soft rot in early stages and no browning, whereas those from the uncovered load arrived with 3 per cent bacterial soft rot and some slight browning, and 2 per cent severe browning.

CONCLUSIONS AND RECOMMENDATIONS

During this investigation the conditions and practices contributing to the best carrying quality of new Kern County potatoes to markets as far distant as Chicago were as follows: the digging of relatively mature stock (at least 115 days from planting), morning digging, immediate pickup in sacks and by truck in the field, the use of tarpaulins over the load during hauling to the washing shed, and shipping under refrigeration. The hydrocooling of the tubers in ice water to about 50° F, followed by immediate icing of the car under Rule 240, controlled discoloration and decay and gave the best results of any of the test shipments.

SUMMARY

Shipping and holding tests with new potatoes from Kern County, California, were made during the seasons of 1938, 1939, and 1941. The shipments were inspected at Chicago and New York after being 7 to 9 days en route. Recording thermometers placed inside 100-pound sacks of potatoes were forwarded with the cars. Kern County potatoes are produced under heavy irrigation and harvested during hot, dry weather. Deterioration in transit consisted mostly of discoloration of skinned tubers and superficial bacterial soft rot which formed a sticky film, particularly on skinned areas and scald spots. Holding tests in which skinned tubers were held for 7 days at 70° and 50° F, at both high and low humidities, were used to determine effect of wind injury.

Most of the commercial stock from this district is washed and shipped in 100-pound sacks. At the peak of the harvest (June), the temperature of the tubers when loaded is between 75° and 90° F. Stock dug and washed in the morning may be as much as 10° to 15° cooler than that dug in the afternoon. Ventilated shipments in June have a temperature of 65° to 70° en route, with a somewhat lower temperature during the time the shipment crosses the mountains. Refrigerated shipments cool under shippers' Rule 240 (initial ice only) to a point between 45° to 50° on the third or fourth day en route. Potatoes in 100-pound sacks were hydrocooled from 80° to 50° in 15 minutes by passing through a shower of 35° water, and carried in perfect condition. A load was precooled with car fans from 80° to 45° in 6 hours, but wind from the fans caused surface browning.

Severe surface discoloration (browning) of skinned tubers was reduced by refrigeration and was practically eliminated for the 7-day transit period by precooling in ice water. When holding tests were made to compare the effect of immediate icing of cars with that of delayed icing, less deterioration occurred with immediate cooling to 50° F. This was true even though the temperature rose after the fourth day. Poorer results were obtained by slow cooling in which tuber temperature of about 70° prevailed for 2 days followed by 50° for the remaining 5 days of the test. The condition of sticky skins occurring on tubers near the bunkers of cars under refrigeration probably develops during the first 3 days en route while the tubers are cooling slowly under humid conditions. This trouble is apparently eliminated by precooling the tubers in ice water.

When tubers infected with late blight were shipped, an increase in the size of the lesions was observed but there was no spread of the disease to sound tubers, either under conditions of icing at the first icing station or by delaying icing for several days.

Exposure to wind or hot soil soon after digging increases surface browning in transit. Browning results from the combined effect of excessive drying and of oxidation of cells injured by skinning and is not immediately noticeable.

10m-4,'42(9041)